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Title: Development of a New Neutron Electric Dipole Moment Experiment at LANL

Author(s): Hassan, Md Taufique

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Development of a New Neutron Electric Dipole Moment Experiment at LANL

Md Taufique Hassan

Nuclear and Particle Physics and Applications (P-3) Group

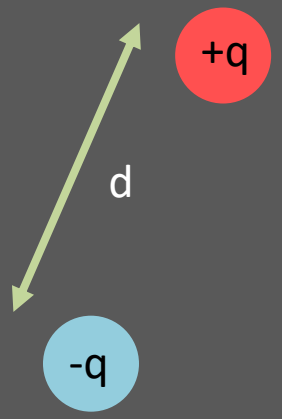
Los Alamos National Laboratory

08/12/2021

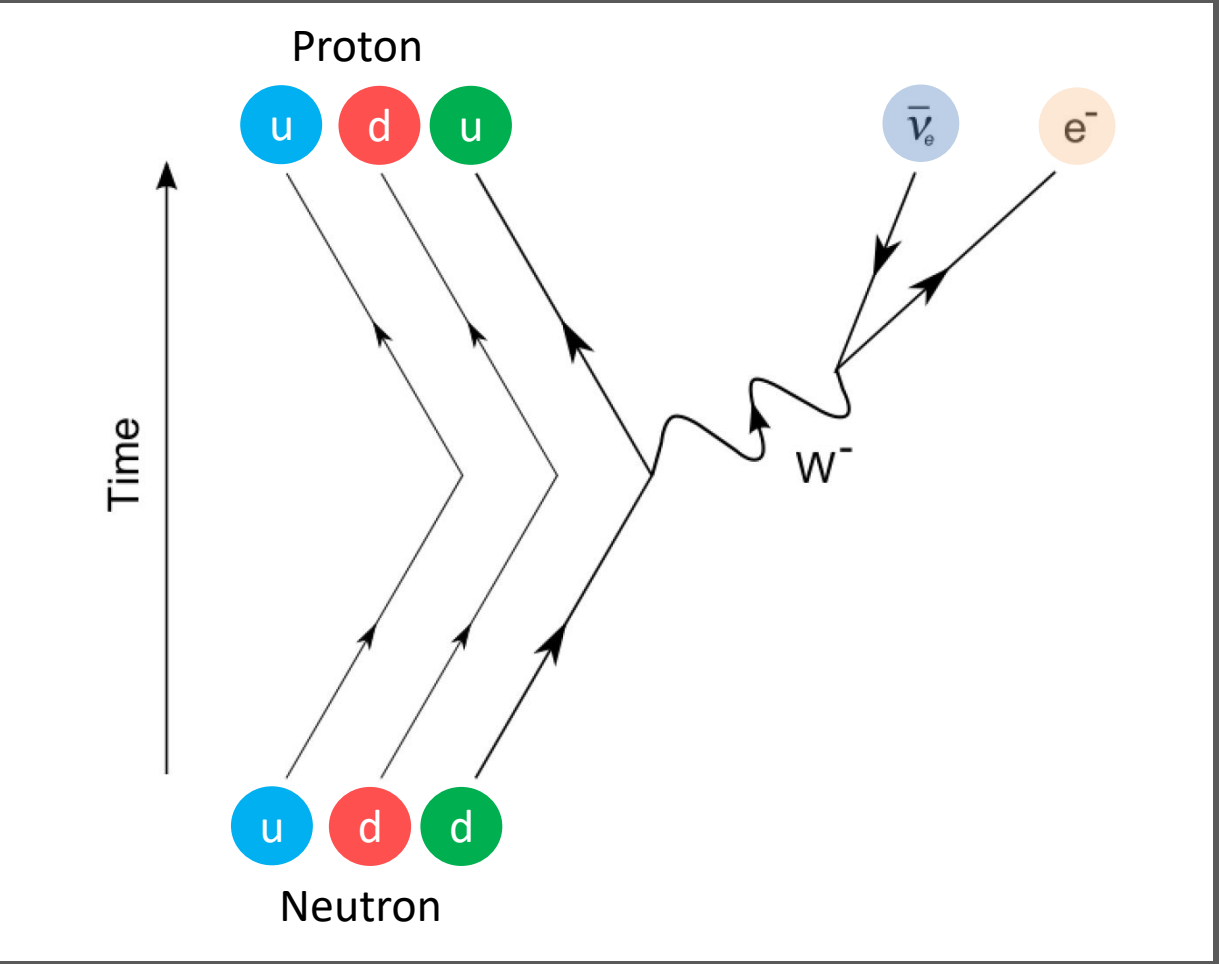
Los Alamos NATIONAL LABORATORY EST. 1943

Neutron Electric Dipole Moment (nEDM)

An electric dipole moment is the asymmetry in a charge distribution



Neutron Beta Decay



$$n \rightarrow p + e^- + \bar{\nu}_e + 0.783MeV$$

Neutron in Fundamental Physics Experiments

- Decay coefficients (e.g. Electron–antineutrino correlation, Spin-electron asymmetry, Spin-antineutrino asymmetry etc.)
- Neutron lifetime
- Neutron electron dipole moment (nEDM)

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Neutron in Fundamental Physics Experiments

- Decay coefficients (e.g. Electron–antineutrino correlation, Spin-electron asymmetry, Spin-antineutrino asymmetry etc.)
- Neutron lifetime
- Neutron electron dipole moment (nEDM) with ultracold neutrons (UCN)

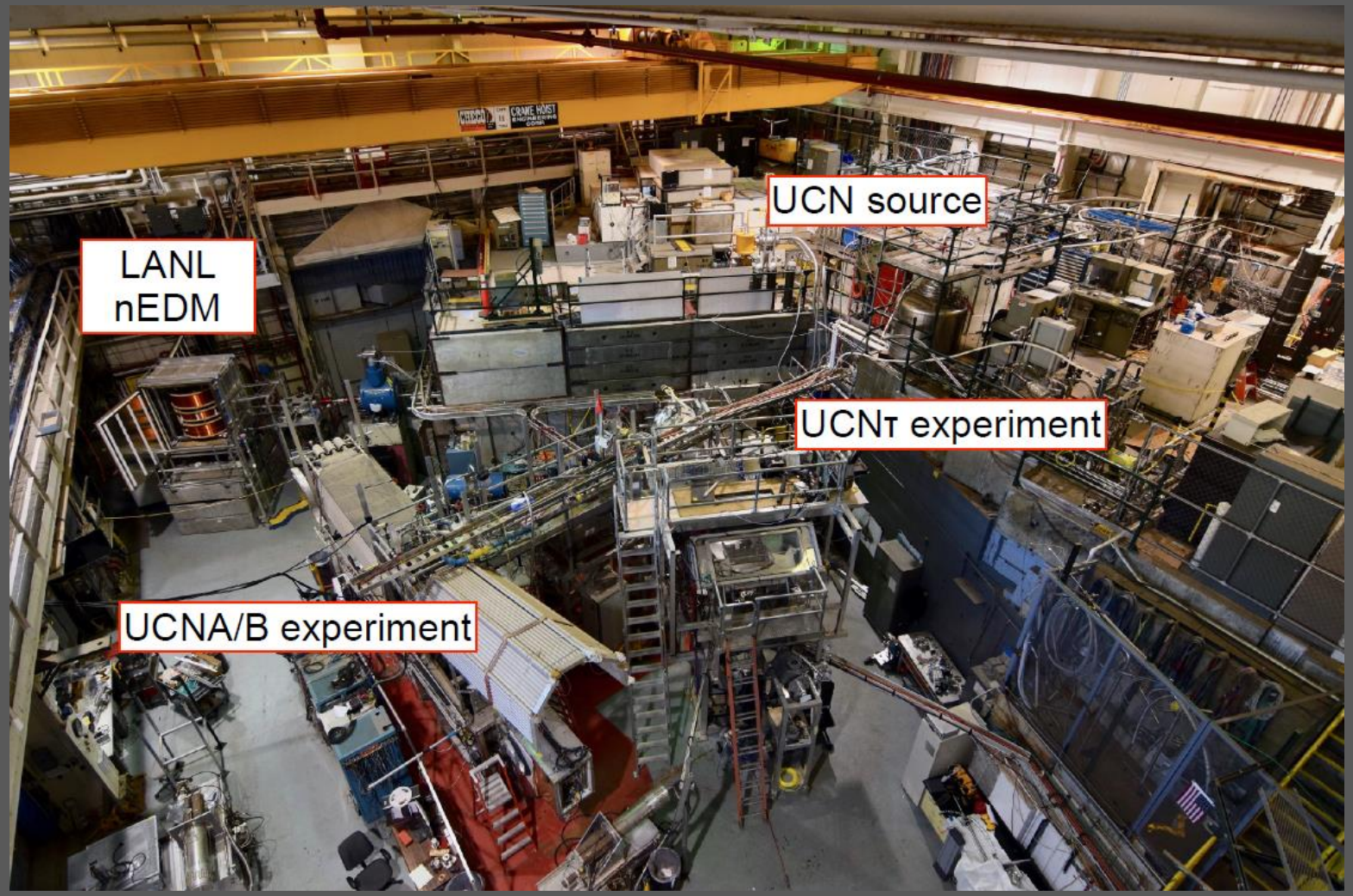
Some Ultracold Neutron (UCN) Properties

- KE less than 350 neV (at LANL UCN guides: < 200 neV)
- Speed < 7.6 m/s
- UCN wavelength: about 0.1 μm
  - close to visible light
  - mirrors for people can be mirrors for UCN
- 100% polarization is easy to achieve magnetic interaction (1 T = 60 neV)
- Gravitational interaction (1m = 100 neV)

Some Ultracold Neutron (UCN) Properties

Material	Fermi Potential (V_f)
Ni^{58}	335 neV
Dimond	304 neV
BeO	257 neV
NiP	213 neV
Iron	210 neV
dps (deuterated polystyrene)	209 neV

LANL UCN Experimental Area



LANL nEDM Collaboration

T. Chupp, S. Clayton, C. Cude-Woods, S. Currie, M. T. Hassan, T. Ito, M. Makela, C. Morris,
C. O'Shaughnessy, A. Saunders, Z.Tang, W. Uhrich, A. Urbaitis,
Los Alamos National Laboratory

C. Swank
California Institute of Technology

T. Chupp, N. Sachdeva
University of Michigan

J. Chen, F. Gonzales, C. Hughes, C.-Y. Liu, J. Long, A. Reid, W. Snow, D. Wong
Indiana University

J. Brewington, W. Korsch, M. McCrea, P. Palamure, B. Plaster
University of Kentucky

R. Pattie Jr.
East Tennessee State University

S. Stanislaus
Valparaiso University

T. J. Bowles and B. Heckel
University of Washington

S. K. Lamoreaux
Yale University

E. Sharapov
Joint Institute of Nuclear Research

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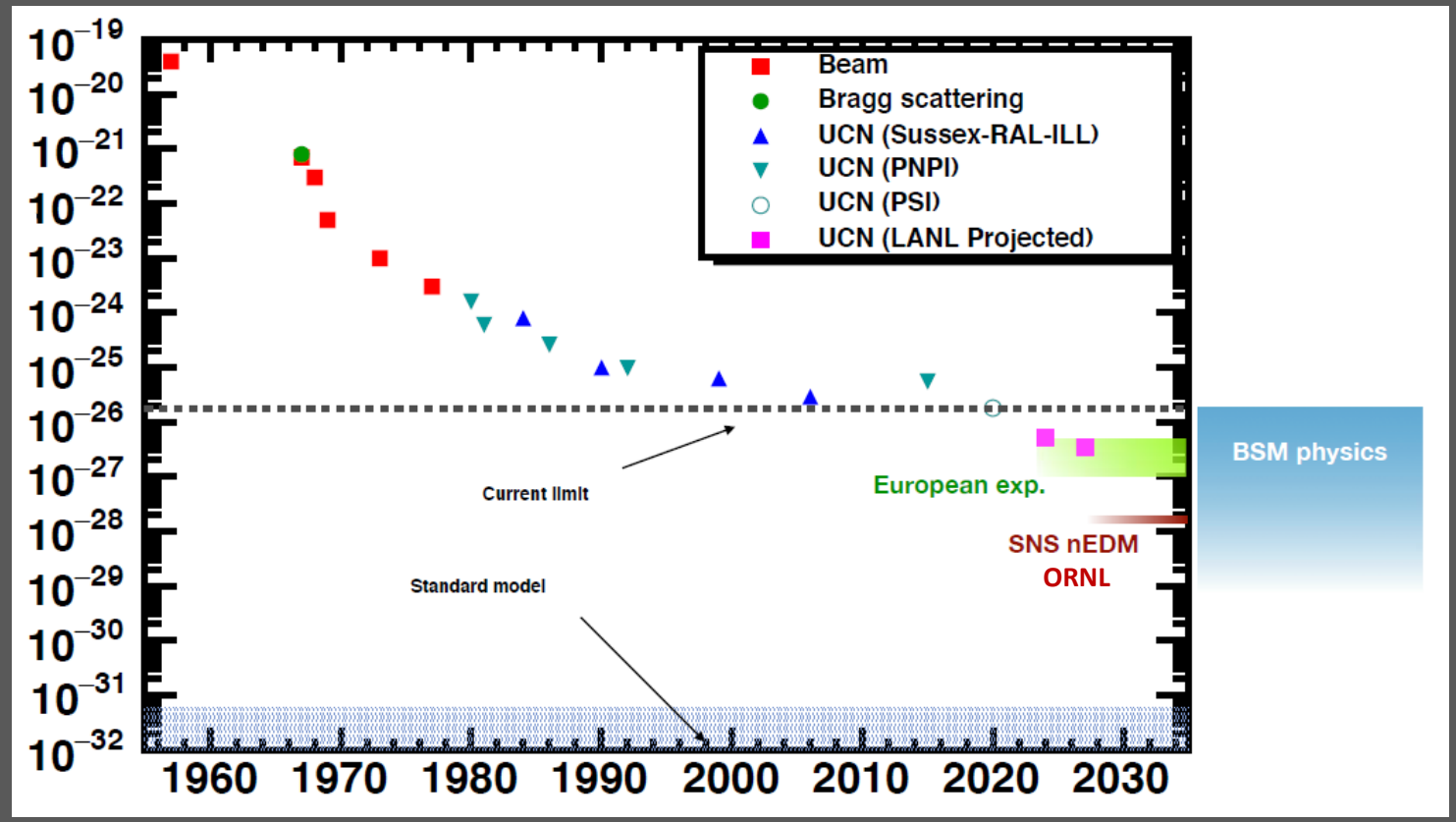
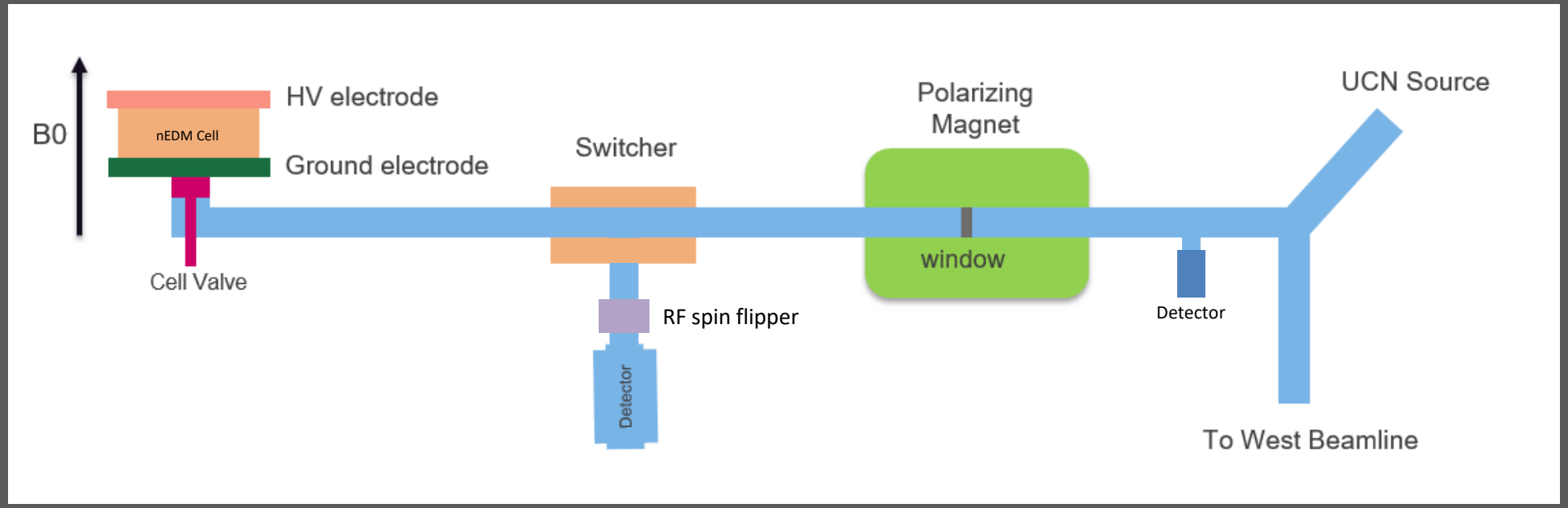
Motivation for the LANL nEDM Experiment

- Current limit is at **10^{-26} e cm**
- The Lanl nEDM search is aiming for **10^{-27} e cm**



The LANL nEDM Experiment



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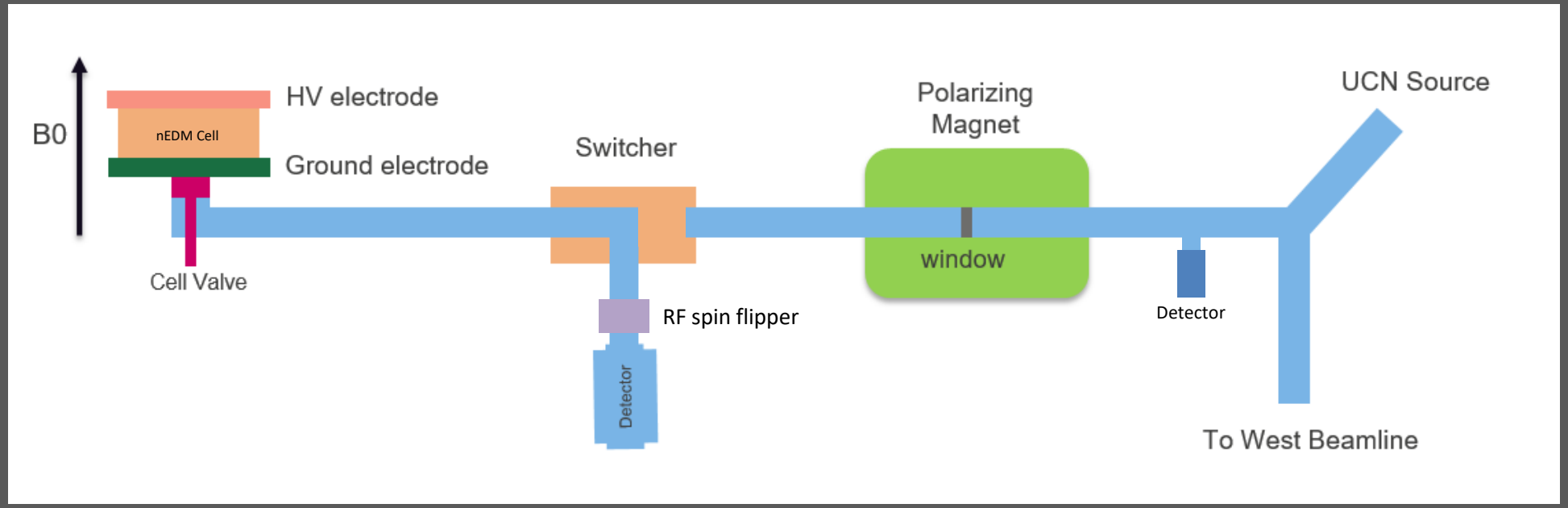
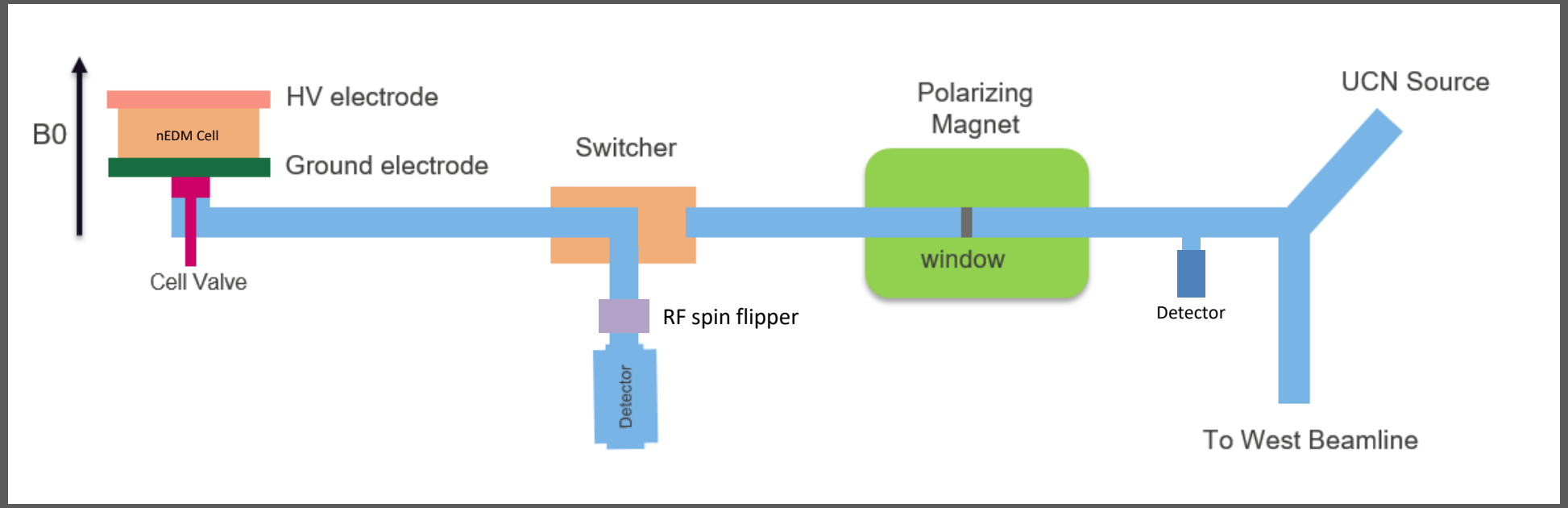


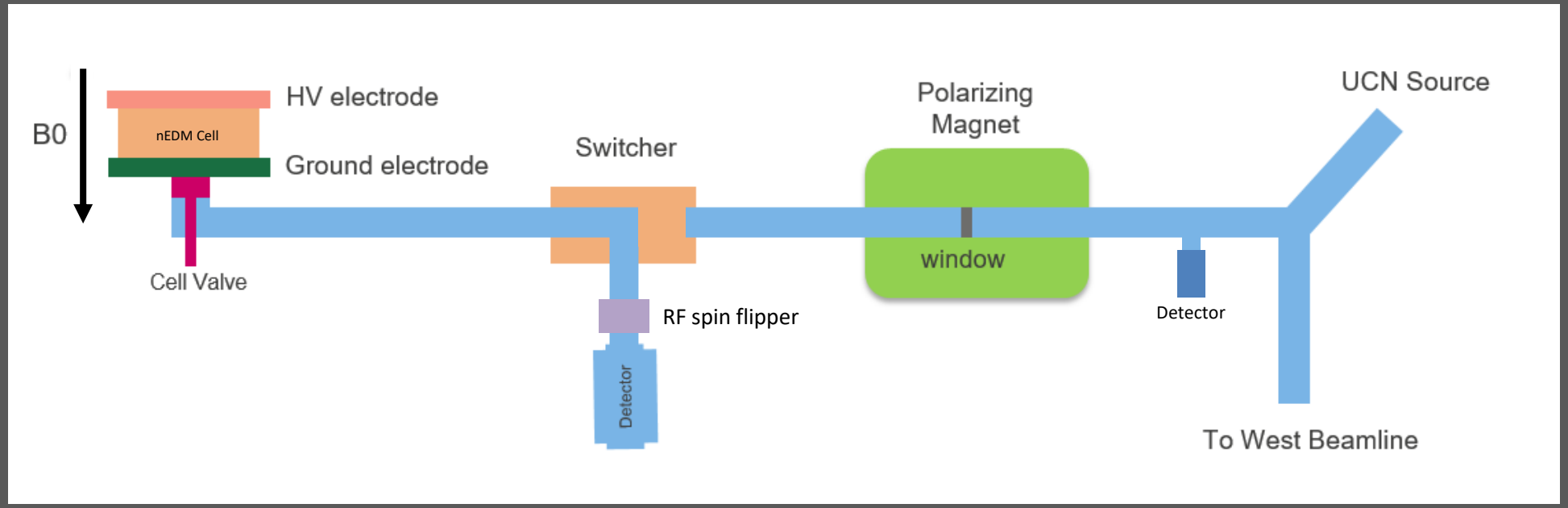
The LANL nEDM Experiment



$$H = -(\vec{\mu}\vec{B} + \vec{d}\,\vec{E})$$

$$h\nu_{\uparrow\uparrow} = |2\mu_n B + 2d_n E|$$

The LANL nEDM Experiment

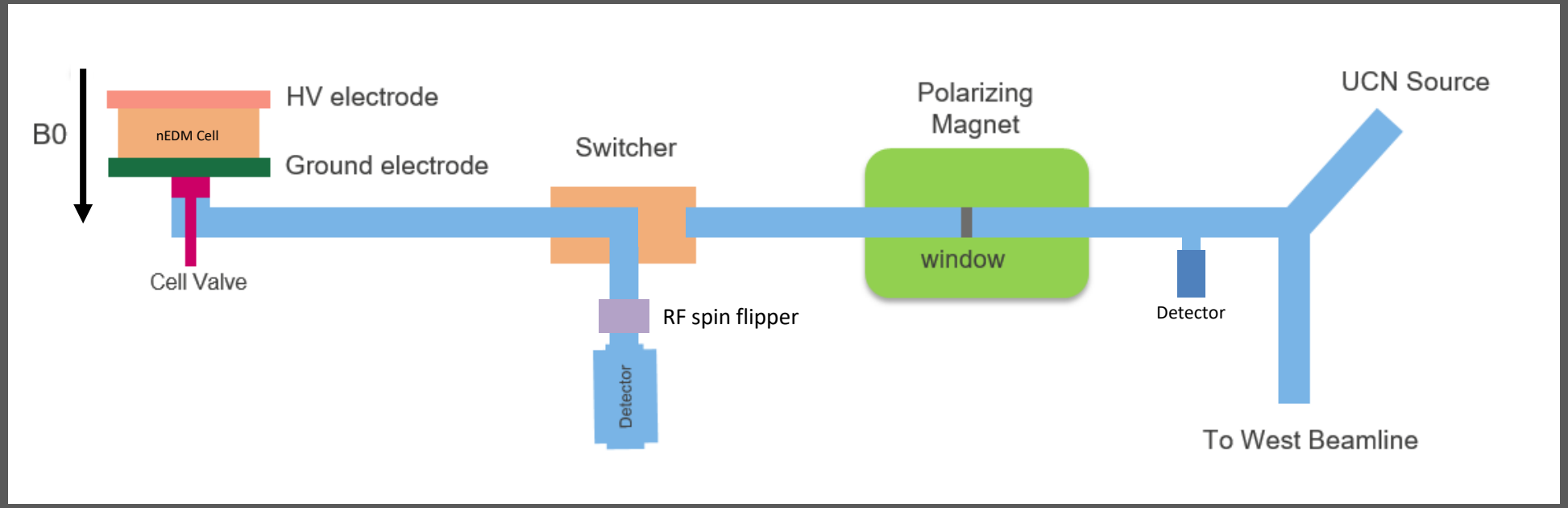


$$H = -(\vec{\mu}\vec{B} + \vec{d}\,\vec{E})$$

$$h\nu_{\uparrow\uparrow} = |2\mu_n B + 2d_n E|$$

$$h\nu_{\uparrow\downarrow} = |2\mu_n B - 2d_n E|$$

The LANL nEDM Experiment



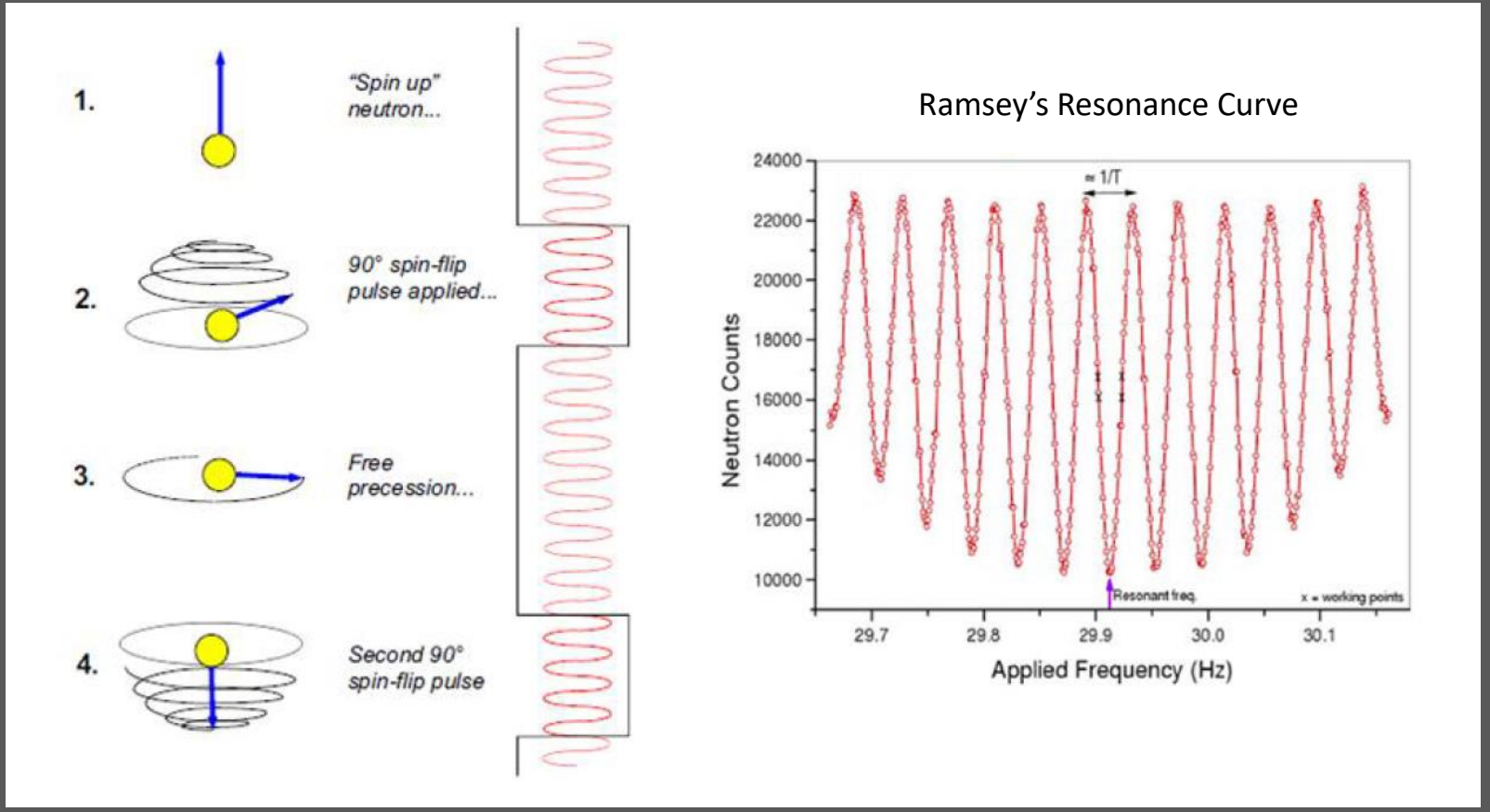
$$H = -(\vec{\mu}\vec{B} + \vec{d}\,\vec{E})$$

$$h\nu_{\uparrow\uparrow} = |2\mu_n B + 2d_n E|$$

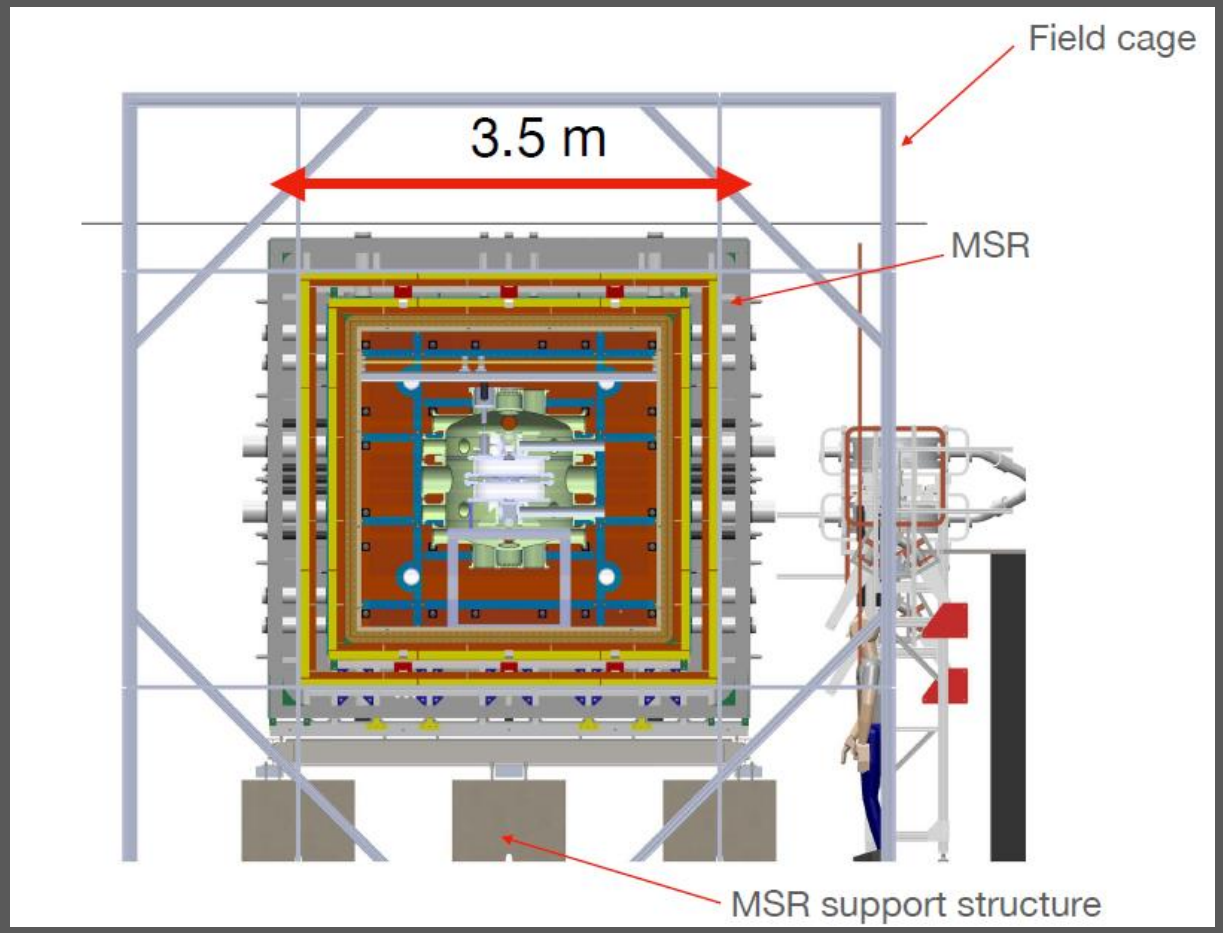
$$h\nu_{\uparrow\downarrow} = |2\mu_n B - 2d_n E|$$

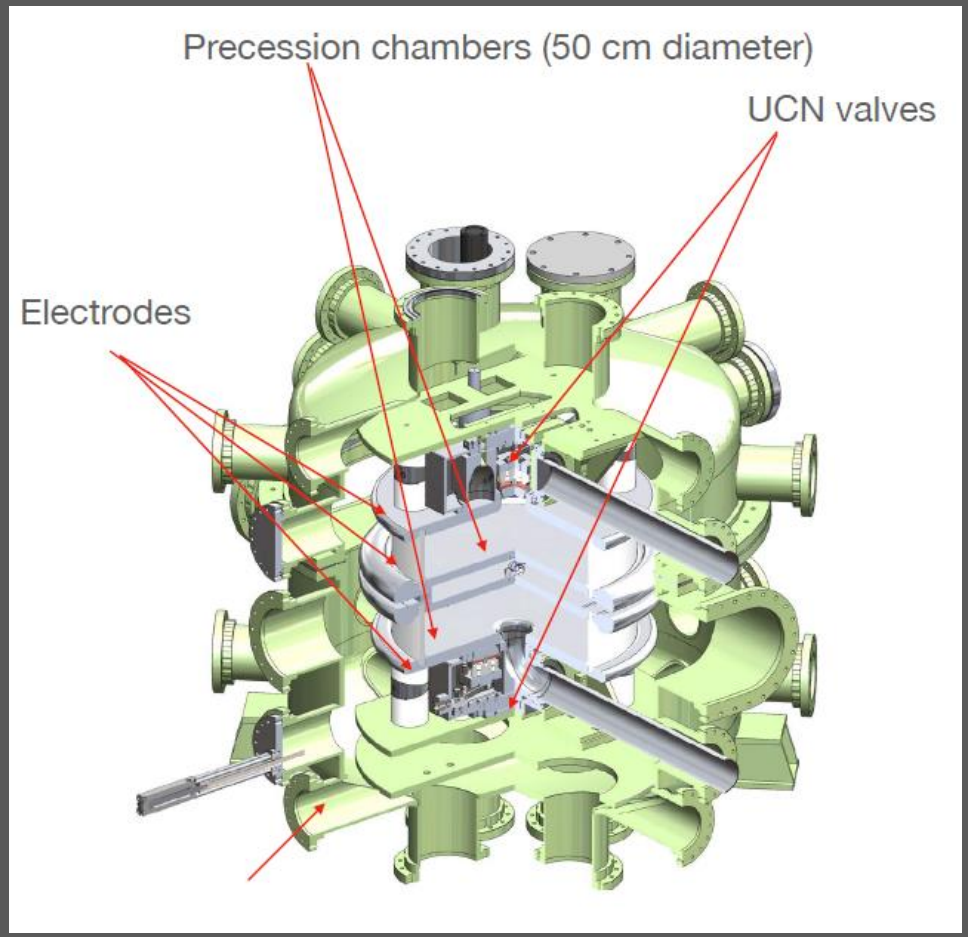
$$\Rightarrow \quad d_n = \frac{h(\nu_{\uparrow\uparrow} - \nu_{\uparrow\downarrow})}{4E}$$

The LANL nEDM Experiment



The LANL nEDM Experiment



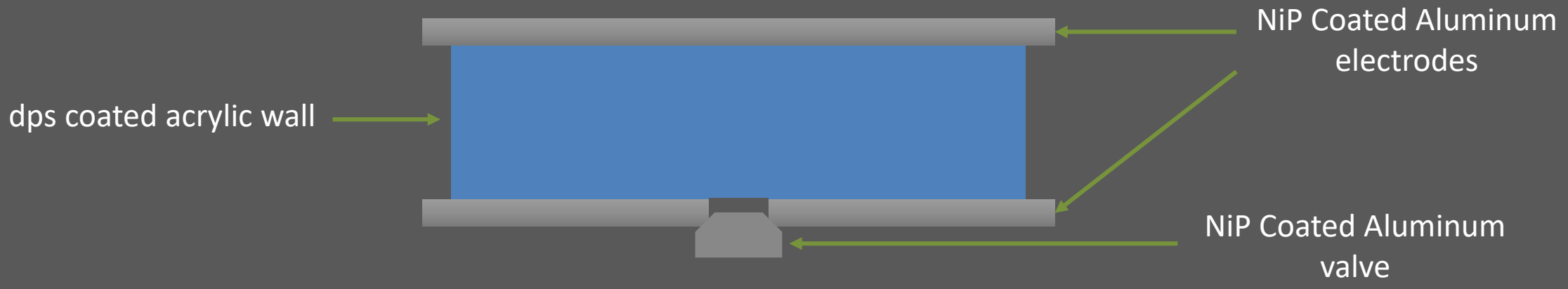


R&D for the LANLnEDM Experiment

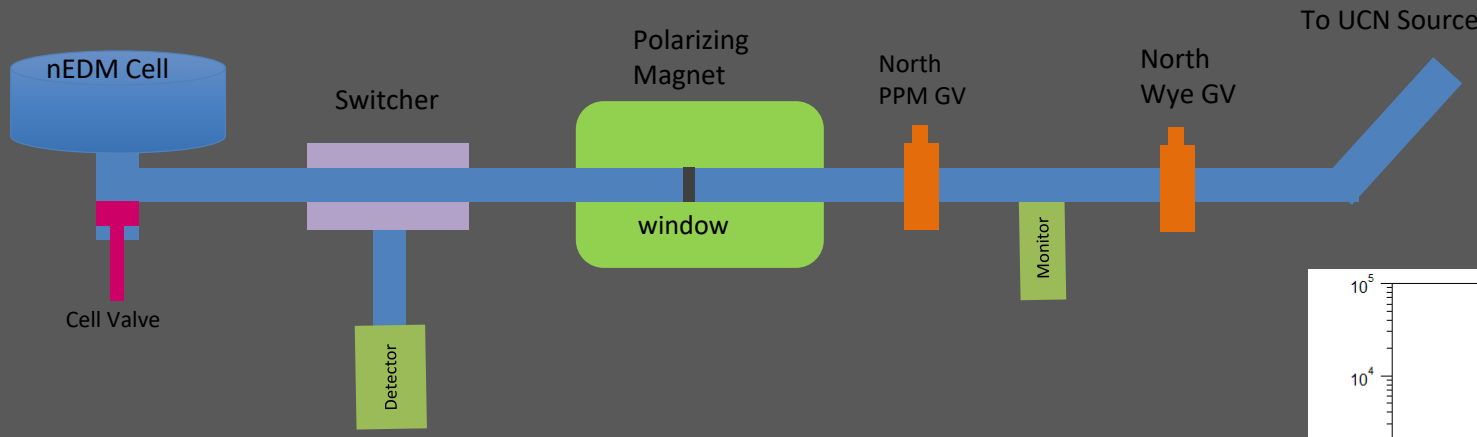
- UCN cell
- Vacuum Chamber
- New switcher with simultaneous spin analyzers
- Field cage, Magnetically Shielded Room (MSR)
- B0 coil, Magnetometry

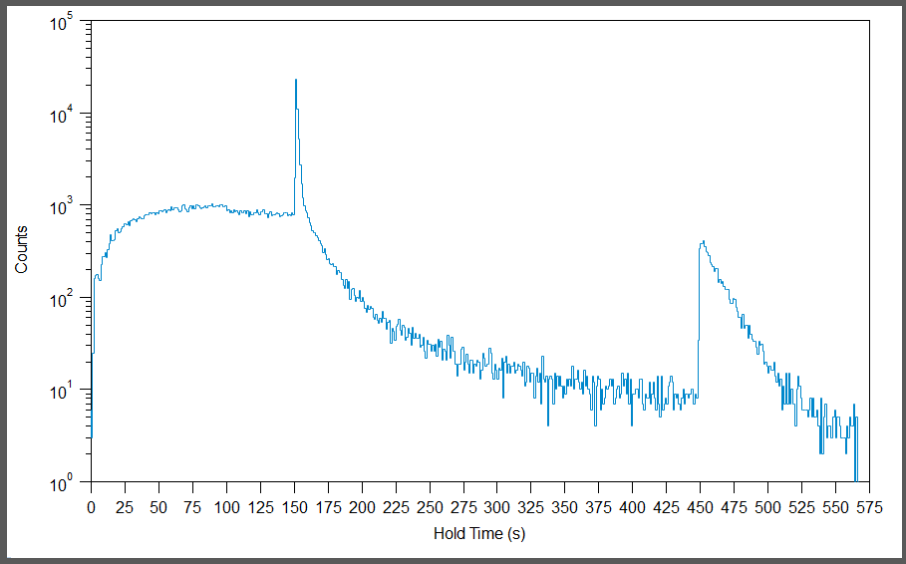
UCN cell

- NiP Coated Aluminum electrodes
- Acrylic (PMMA) wall with (ID: 50 cm, Height: 10 cm) Deuterated Polystyrene (dps) coating



Storage Measurement in the Cell





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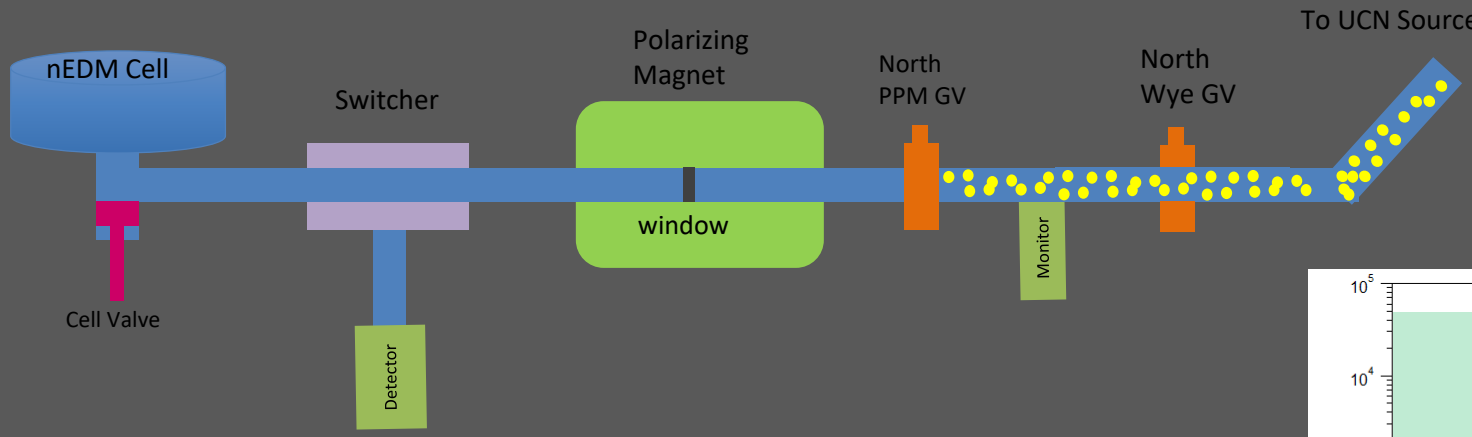

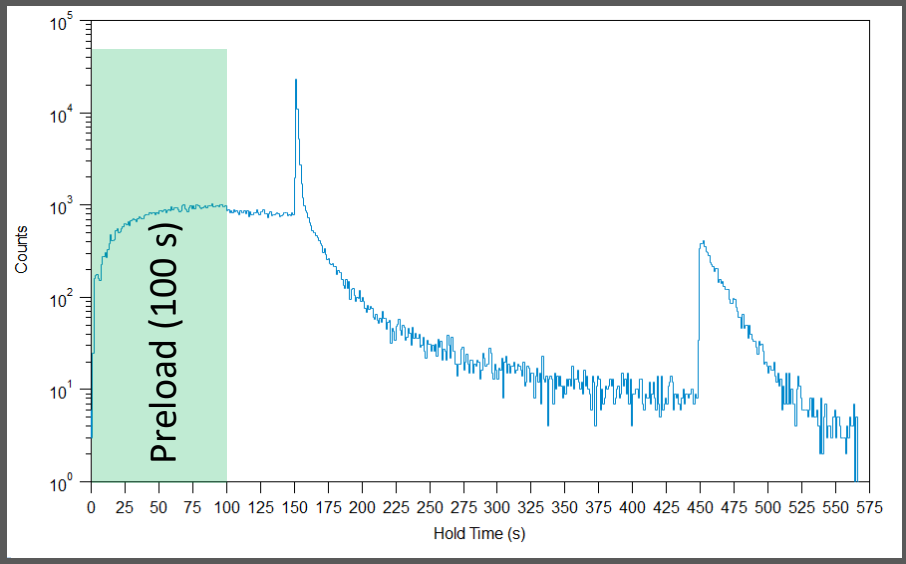

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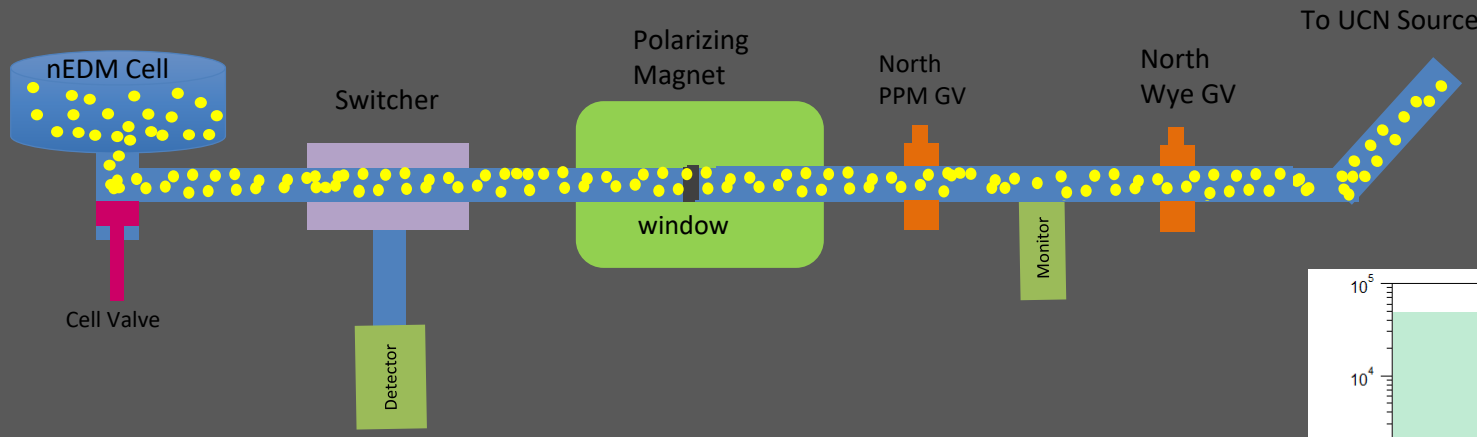
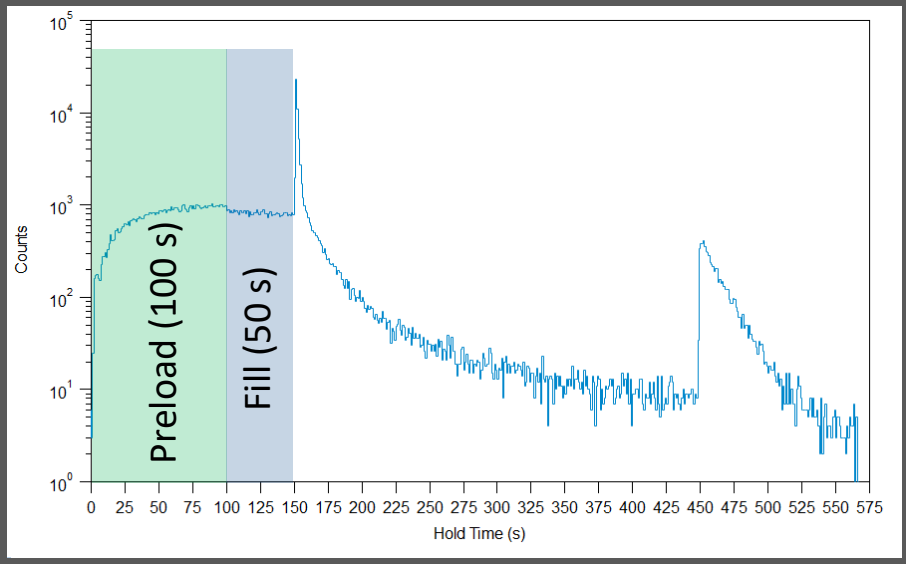
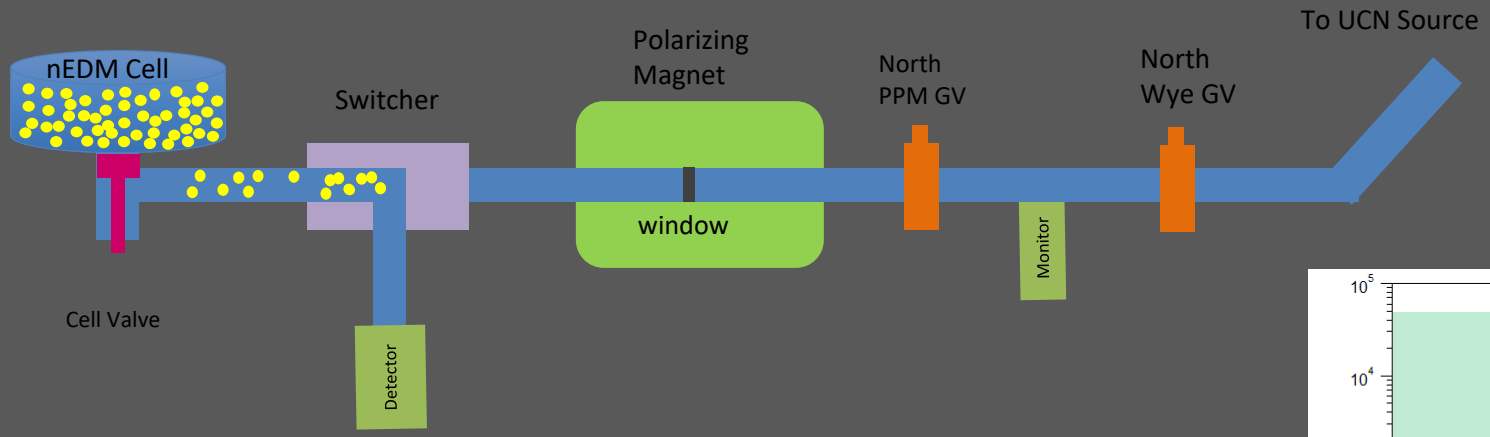
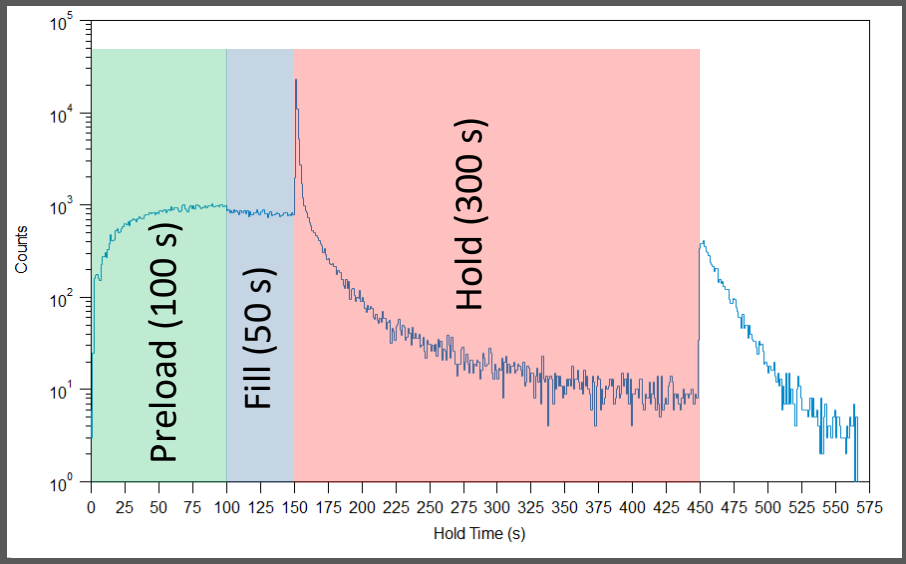




Storage Measurement in the Cell





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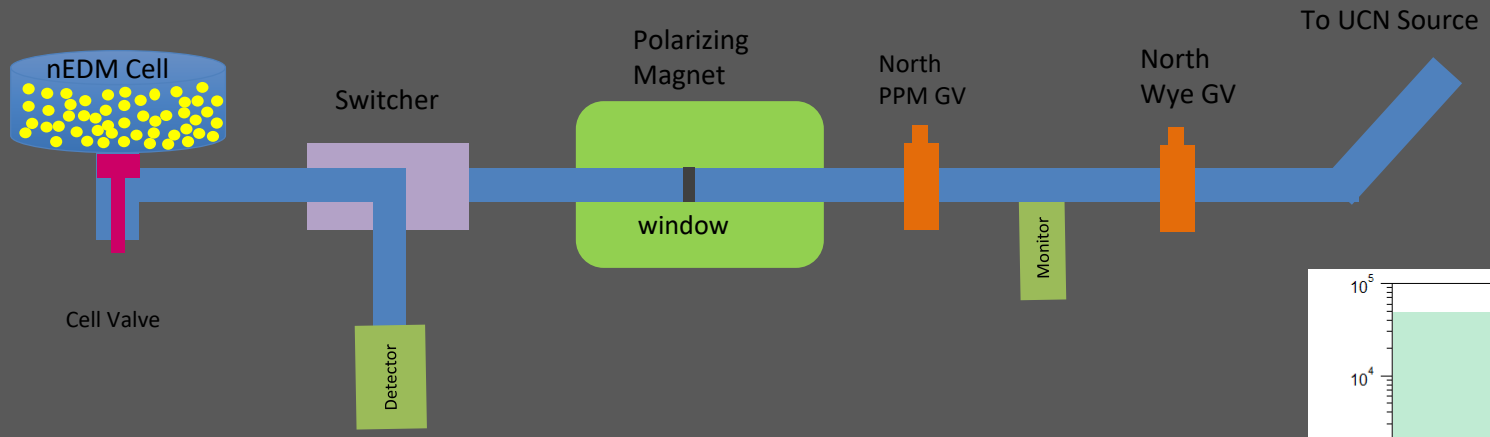

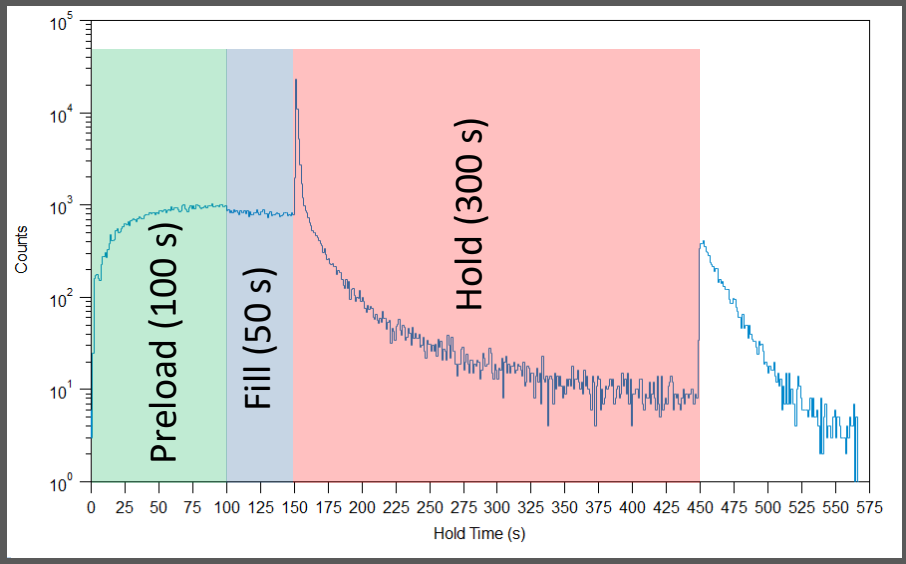

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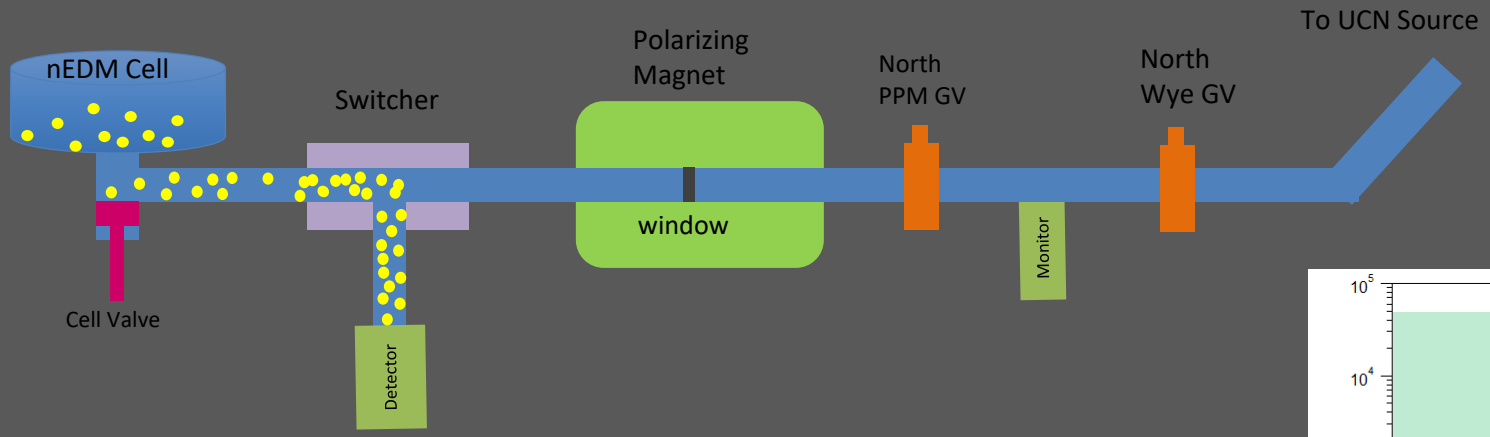

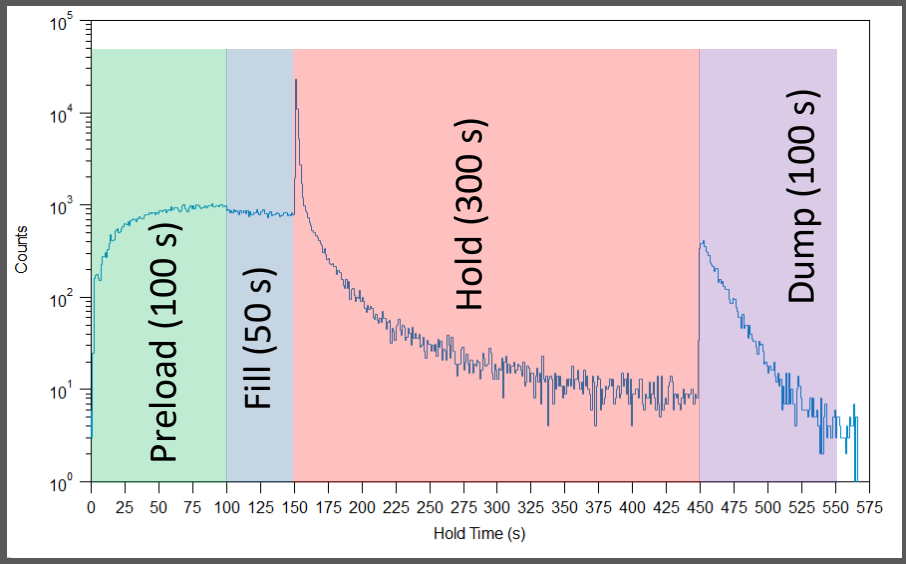

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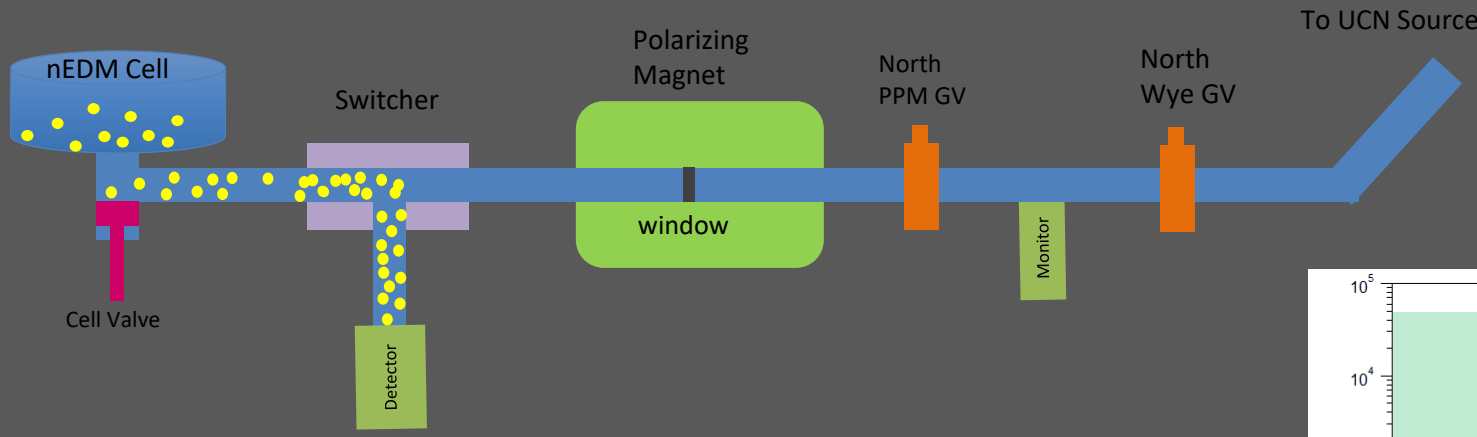
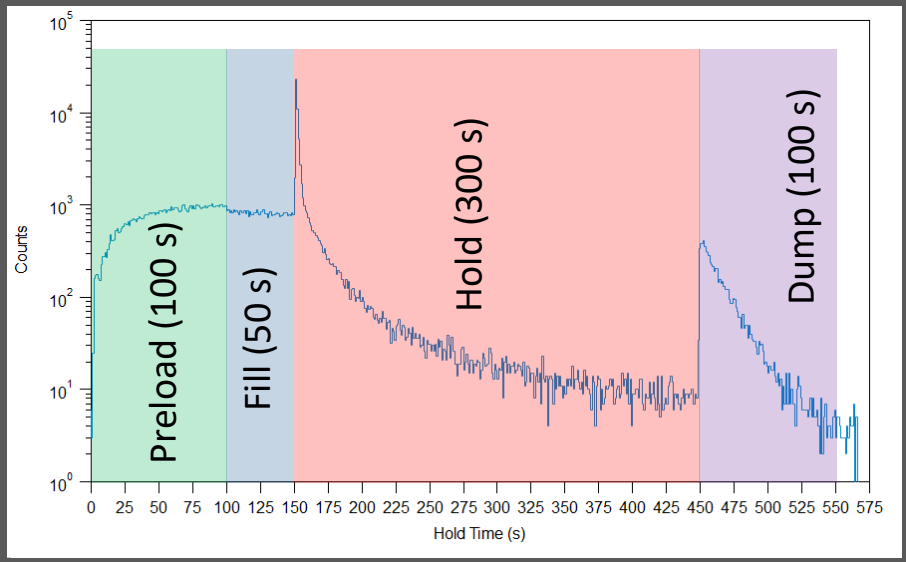


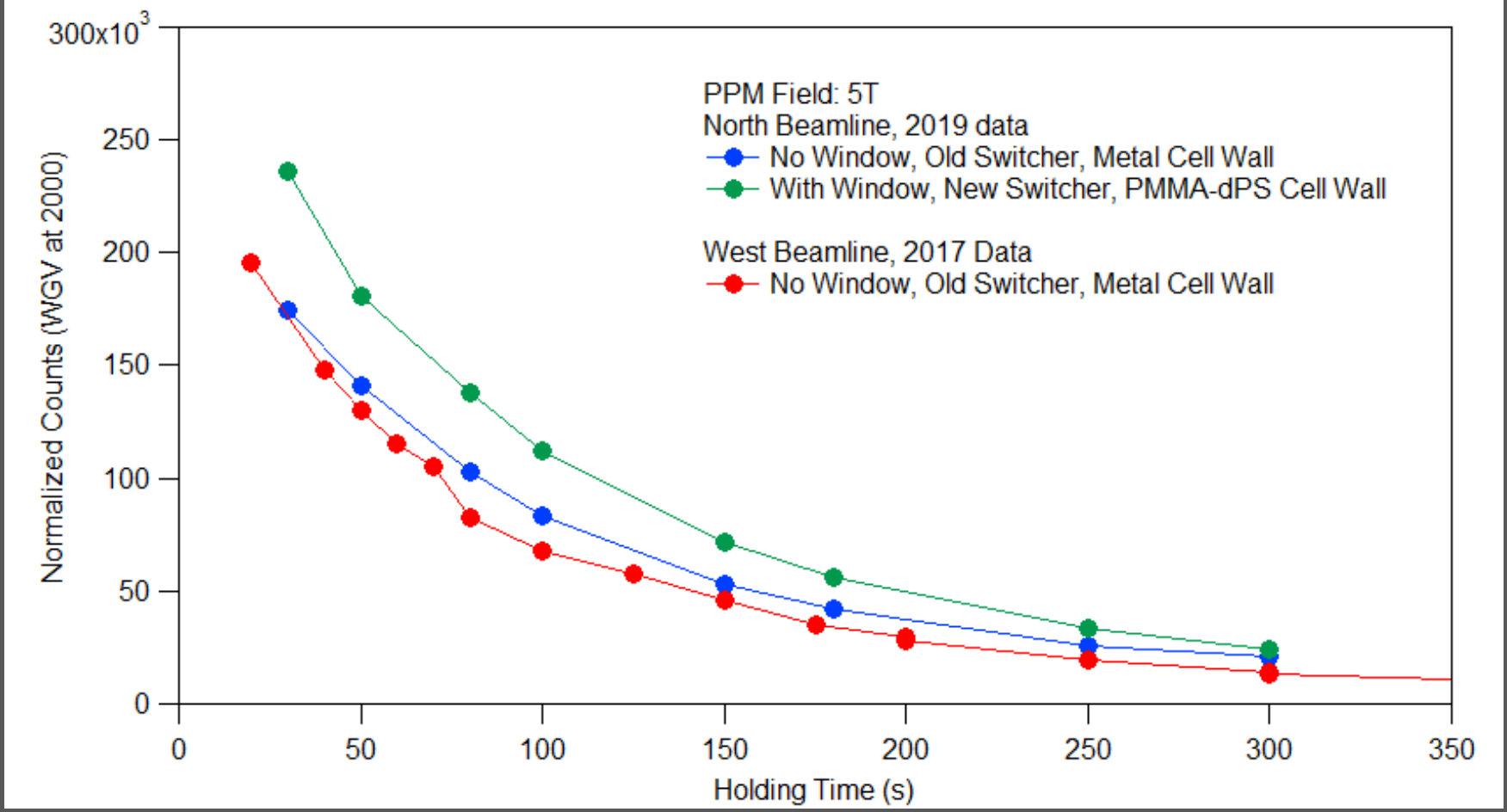


Data was taken in different configurations:

- Varying holding time
- With and without the PM window
- At different PM field (for benchmarking the simulation)

Storage Measurement in the Cell

World's highest demonstrated stored UCN density for nEDM experiment



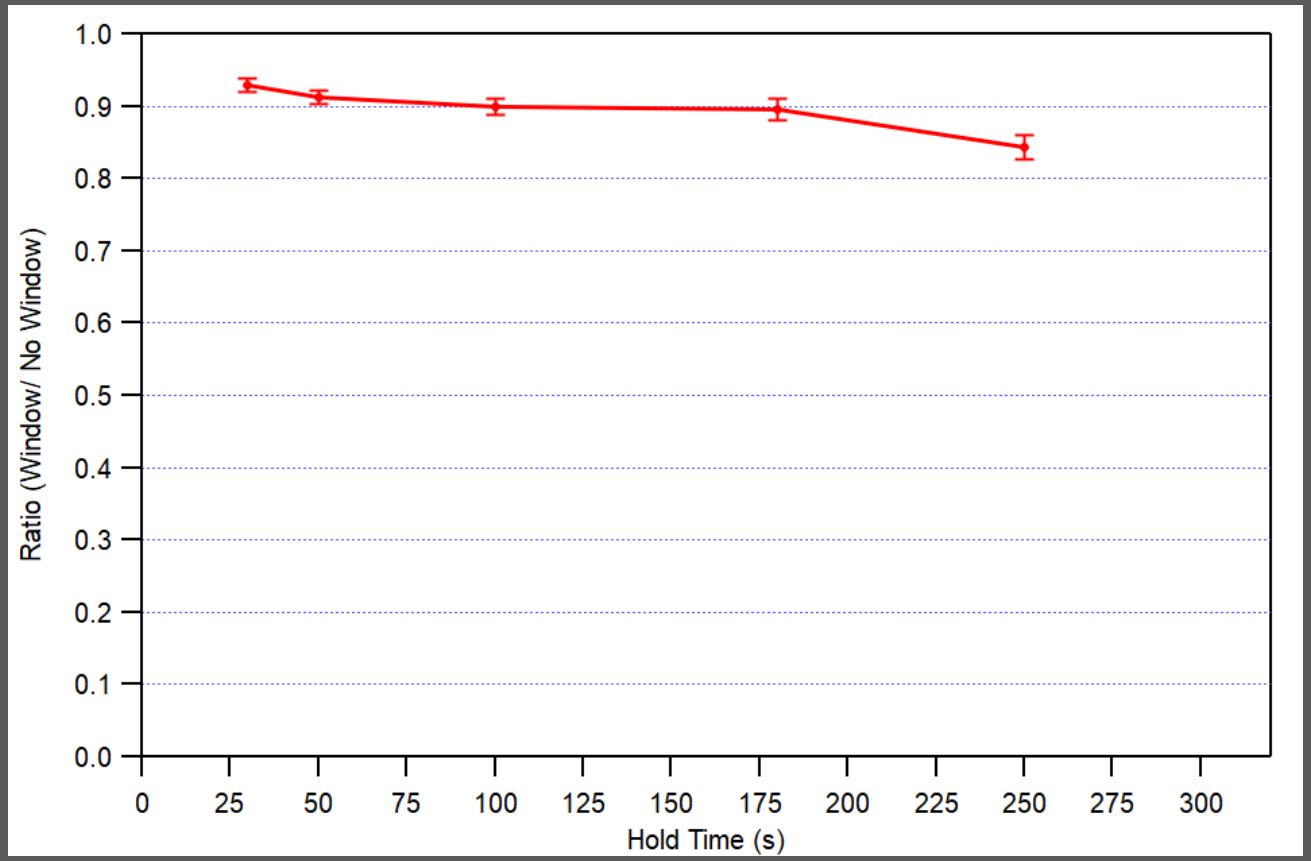
Storage Measurement in the Cell

Average UCN loss (at 5 T field)

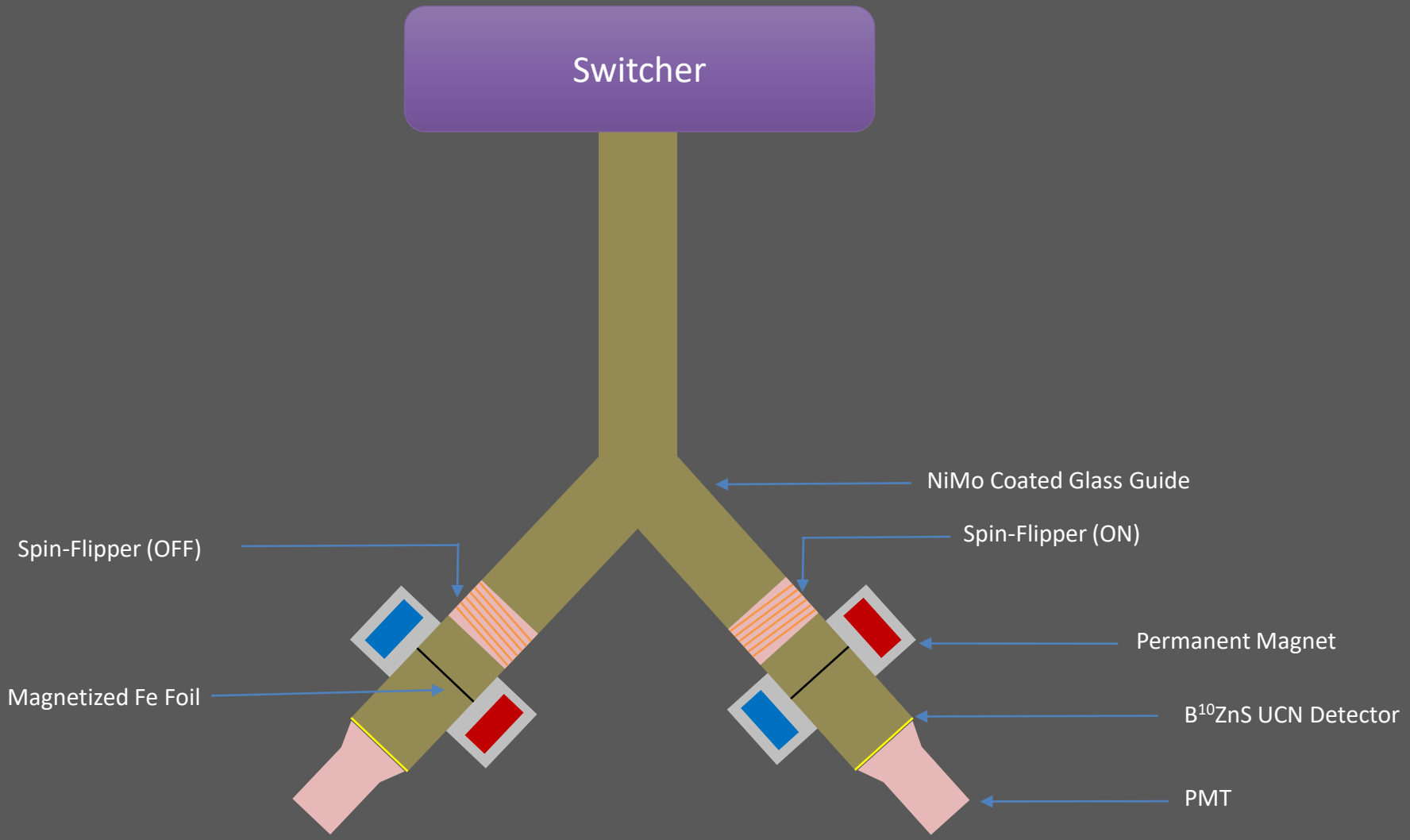
due to a 0.003 in thick aluminum

window =

(10.38 ± 2.84)%



Simultaneous Spin Filter



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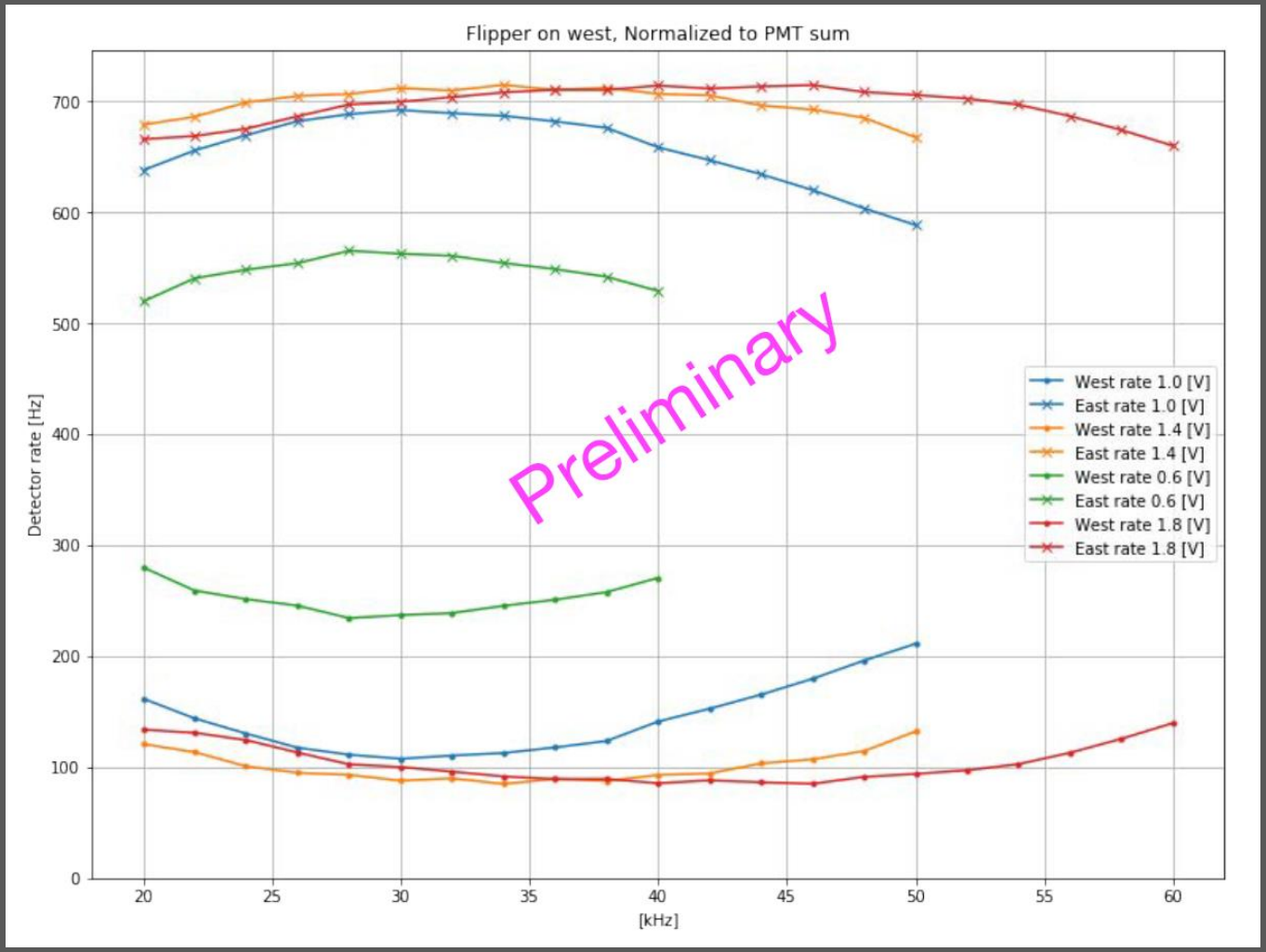
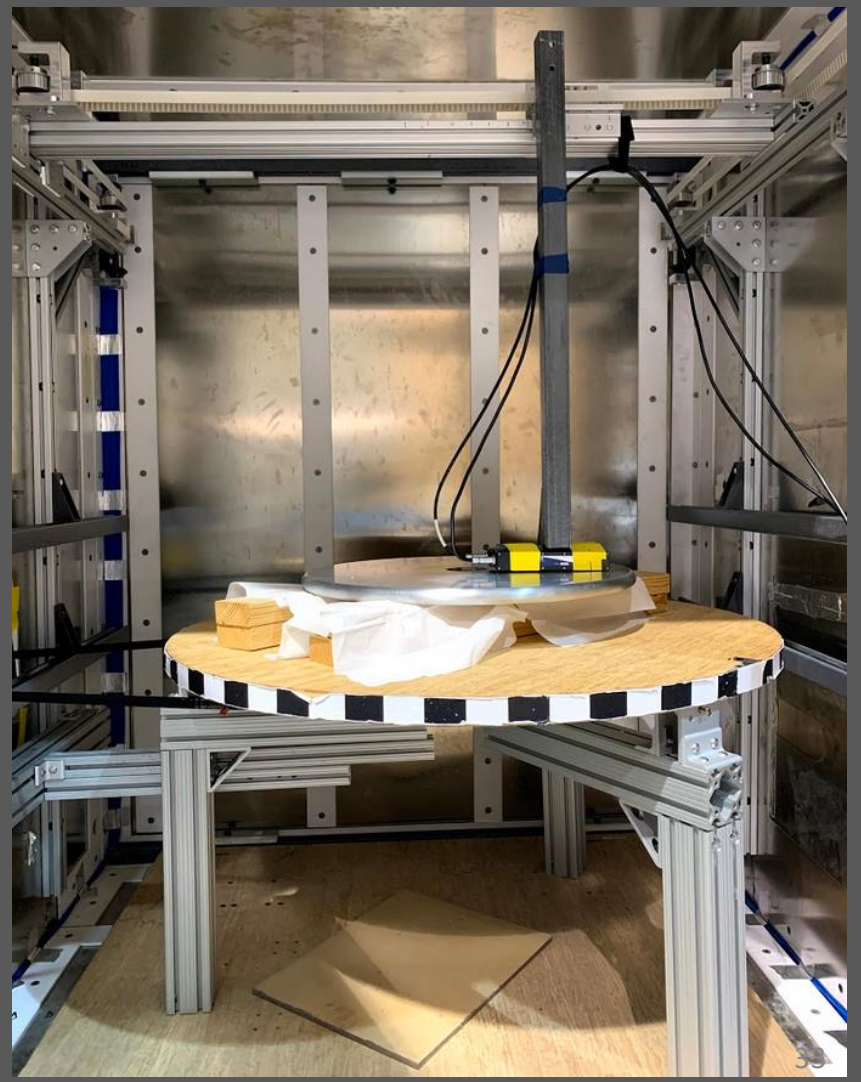


Scanning for Magnetic Impurities

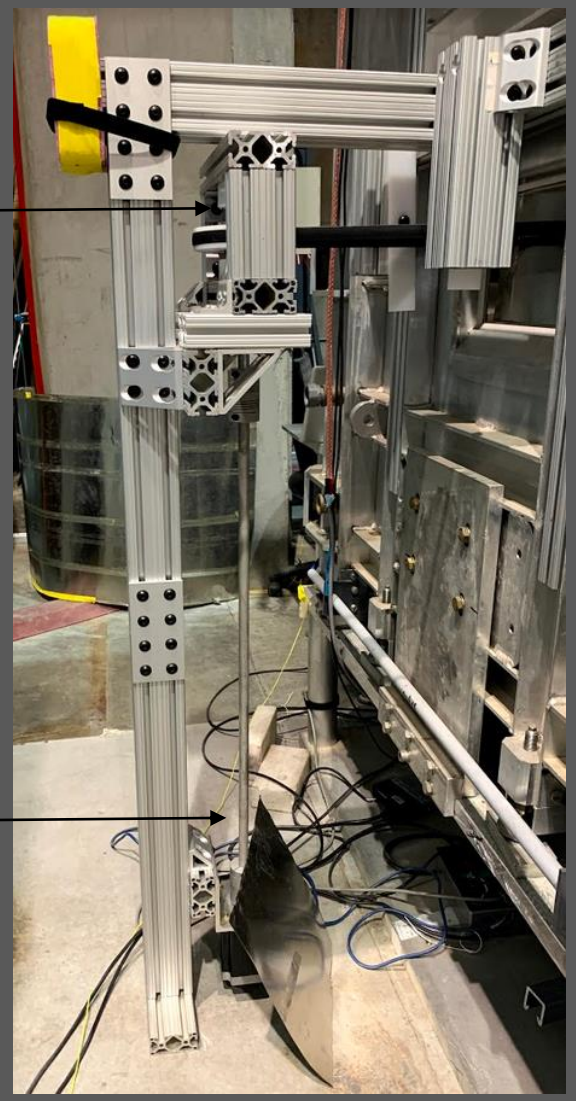
- The electrodes are put on the turntable
- There are two fluxgates (Mag-13MSQ100)
- Distance from the fluxgate sensor to the surface of the object is 0.75 in
- Fluxgate output fed into a Bartington SCU1 (signal conditioning unit), gain at 1000x.
- Turntable rpm: 0.5

- Sensor field direction
  - +Bx: Down
  - +By: Away from the door
  - +Bz: Away from the big MSR

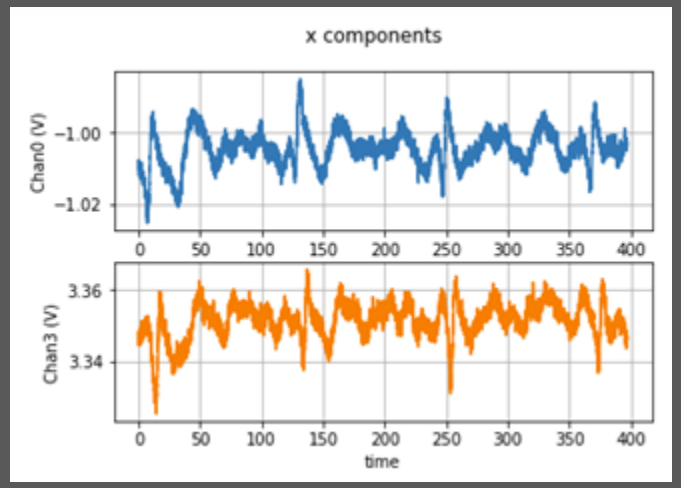


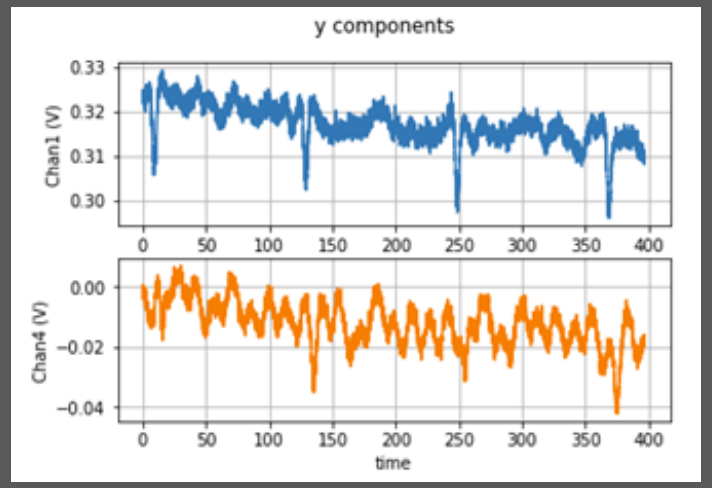
Scanning for Magnetic Impurities

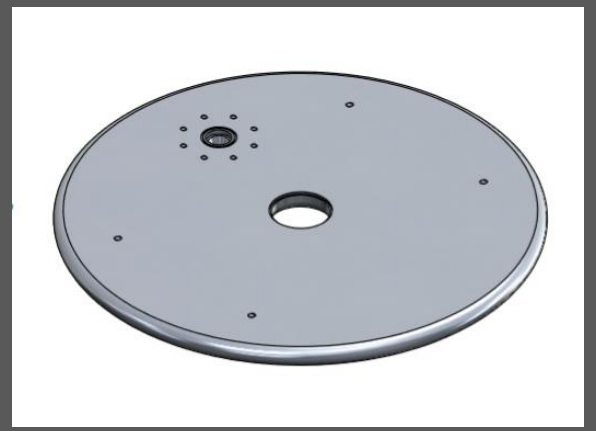
The turntable is turned using a motor from outside of the magnetically shielded room (MSR).

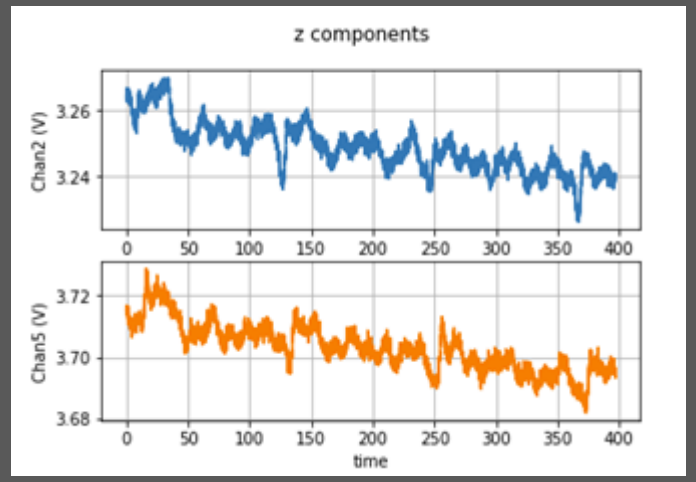


Scanning for Magnetic Impurities









Updates on other Important Components

Field Cage:

- For cancelling the ambient magnetic field
- Installed and tested

Updates on other Important Components

Magneticially Shielded Room (MSR):

- Being installed (by MSC and LANL)
- Partially tested

Updates on other Important Components

Vacuum Chamber:

- Made of fiberglass with resin (Derakane 411)
- Checked for magnetic impurities
- Being vacuum tested

Conclusion

- New timing filter amps and power supplies for the PMTs have been procured
- The second switcher is built and will be tested with UCN soon
- The second simultaneous spin analyzer is being built at Indiana University and will be tested this year
- We plan to start taking production data from next year.

Thank you for your attention